Time Series analysis of Residential Energy Demand Forecast in Nigeria

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Abstract

The supply of efficient, reliable and affordable electric power is a panacea to foster development in any country. Development of electricity infrastructure is undoubtedly a capital intensive project that must be carefully and holistically planned especially when future expansion frame work is taken into consideration. For Nigeria to keep pace with other developed countries which have exhibited a substantial growth in economic development, the existing gap between the electric power demand and supply of the country must be bridged. Till now, Nigeria is still entrenched in constricted opportunity for development due to frequent outages resulting from shortage in generation, as well as inadequate transmission and distribution infrastructure. Within the ambient of socio-economic development and increase in human population electric load demand is on the increase over the years. This research studies a load demand forecasting for residential section of the power sector using time series as a tool for analysis. The outcome shows there is need to constantly improve power generating, transmission and distribution network to deliver at least 20,000mw of power to its residents in other to meets the estimated or forecasted power of 19576.05 MW in the year 2030

Keywords: *Electricity consumption, energy management, Time series analysis, energy forecast.*

1. Introduction

Power holding company of Nigeria (PHCN) was empowered to generat, coordinate and maintain the economic system of electricity distribution to all the nooks and crannies of the nation; that will propelled the nation's technological and industrial growth. PHCN has become the fastest and biggest growing electricity industry in Africa and indeed the developing world with an average consumer population of about sixty million [1]. It is very important to recognize that the forecast of power demand in Nigeria must be performed during and as an integral part of the power system design process. It is not practical to add the load forecast at a later date and an attempt to do so could prove unrewarding and involves considerable and unnecessary cost even if it is physically possible. Load forecasting is needed to coordinate transmission and distribution outages over the system and reduce system failure rate. The later section of this research focuses on the long term load forecasting of Nigeria electricity demand, and the method of forecasting employed is the stochastic/probabilistic extrapolation method which is based on the time series analysis of past load demand curve using straight line graph/curve (y = a + bt).

This study is essential to be able to predict /forecast the quantity of power needed by Nigeria owing to the epileptic nature of the Nigerian power supply and plan future network expansion, reduce cost of energy generation, stop load shedding and reduce power outages to minimum with special emphasis on the residential area of the power sector.Energy is essential for all human activities and, indeed is critical to social and economic development. Energy is only one of the many important inputs for production, conversion, processing and commercialization in all sectors [2]. It is generally recognized that energy, including electricity, plays a significant role in the economic development of a country as it enhances the productivity of the nation when inputs such as capital and labor are considered. In *addition, the increased consumption is an indication of increase in economic activities, and by inference, an improvement in economic development of energy signifies that a country has high economic ranking.*

Energy demand is important as it affects the economy which in turn affects people's lives (i.e. their income, health, happiness), and their ability to meet basic needs such as the need for infrastructure, as education, health care and so on. Access to electricity is particularly crucial to human development electricity, in practice, is indispensable for certain basic household (residential) activities, such as lighting, refrigeration and the running of household appliances, and cannot easily be replaced by other forms of energy [3].

There is difficulty in designing or evaluating policies and programs intended to address the impact of the use of energy within residents. The aim of this study is to be able to provide an appropriate analysis of how much power or energy do Nigeria need to efficiently, affordably supply/feed its residents; thus what factors contribute to household energy demand. With the objectives as follows:

- *Investigating the dynamics of demand of energy over time in Nigeria*
- *Identifying the effects of the different factors on household energy demand*
- *Forecasting the KW of energy needed for supply to its residence with utmost reliability.*

In 2004, the Power Sector Reform Bill was signed into law thus enabling private companies to participate in electricity generation, transmission, and distribution. By this reform act, the nation has a new map towards achieving a meaningful progress in her power sector. Figure 2 below shows the categories of electricity consumption figures between 1970 and 2004. From the table, the proportion of electricity used for industrial purposes has been on the decrease since 1970 while ***residential*** *consumption has been on the increase. This is easily explained by the epileptic power supply that has forced many of the big industry to generate more of their own power and using less power from the national grid.*

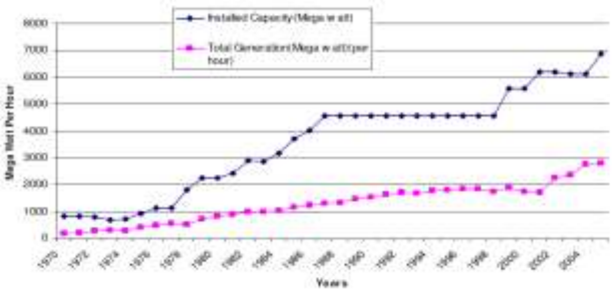

Figure 1: *Electricity Generation in Nigeria, 1970-2004*

Figure 2: *Electricity Consumption in Nigerian, 1970-2004*

2. An Overview of Electricity Generation in Nigeria

The Nigerian economy is heavily dependent on energy. Electricity is used for a number of purposes that include industrial, commercial and residential purposes. Electricity generation in Nigeria began in 1896, fifteen years after its introduction in England. The Nigeria Electricity Supply Company (NESCO) commenced operations as an electric utility company in Nigeria in 1929 with the construction of a hydroelectric power station at Kurra near Jos. The Electricity Corporation of Nigeria (ECN) was established in 1951, while the first 132KV line was constructed in 1962, linking Ijora Power Station to Ibadan Power Station. The Niger Dams Authority (NDA) was established in 1962 with a mandate to develop the hydropower potentials of the country. However, ECN and NDA were merged in 1972 to form the National Electric Power Authority (NEPA). The law which established the National Electric Power Authority (NEPA) in 1972 stipulated that it should develop and maintain an efficient, coordinated and economical system of electricity supply for all parts of Nigeria. At the inception of NEPA in 1973, only five of the then 19 state capitals were connected to the national transmission grid system. Today, practically all state capitals are being served from the national grid, although haphazardly.

As at 2004, Nigeria has approximately 6,861 megawatts (MW) of installed electric generating capacity. As shown in Figure 1, a wide gap between the installed capacity and total electricity generation capacity started emerging in 1978. Thus, making power outages to be frequent and the power sector operates well below its estimated capacity. Low water levels at Kanji, Jebba, and Shiroro hydropower stations are frequently claimed to be responsible for the frequent power shortages, while the Lagos, Egbin, Delta, and Port Harcourt Afam plants are also operating at below capacity due to poor maintenance.

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2.2 Energy Demand Modeling

Since the first oil shock in early 1970s, there has been a significant increase in the number of research studies of energy demand in order to attempt to understand the nature of energy demand and demand response generated by external shocks of that time [3]. According to [4] the debate between engineers and economists of that era guided the important methodological development in energy demand modeling and helped a wide variety of models to be developed for analyzing and forecasting energy demand. [5] argues that computing power, data availability and the training of energy analysts developed over time and as a consequence demand modeling has advanced to a great extent that the early studies in energy demand modeling are identified as simplistic in today's terms.

Energy is a derived demand rather than a demand for its own sake; it is derived from the demand for the end use services that utilize energy resources with the capital stock that uses energy resources to provide these end-use services (such as lighting, heating, motive power, etc.). Therefore, analysis of energy demand should explicitly or implicitly, accommodate the fact that energy resources and energy consuming appliances are combined in different ways to provide these services. [6] and [7]. The consumer makes a choice about the technical and economic characteristics of the appliances such as the technology embodied the fuel type it uses, etc.

As an example, the households' decision to buy a new residential appliance depends upon household income, the climate in which he lives, the cost of purchasing (capital cost) and operating cost (energy costs) the appliance and the general socioeconomic trends that affect the popularity of such appliances. The choice of economic and technological characteristics

of appliances depends upon the comparison of capital and operating costs, reliability, size and efficiency of alternatives. Moreover, the climate or the region where the appliance is used might affect the choice of fuel and other characteristics of the appliances; once the decision about the residential appliance has been made, the capital stock is fixed in the short run. Therefore, the capital utilization of these appliances depends upon the cost of the fuel used by the appliance, income and the other characteristics of the household [7].
Bhattacharyya, S. C. and Timilsina, G. R. argues that an energy demand model should analyses three sets of decision discussed above by taking into account the characteristics of the energy user, the technical and economic characteristics of the energy source and the capital stock, and the characteristics of the environment that the capital stock is used. As the policy implications of energy demand models are important, [7] furthermore states that the variables subject to policy control or that might affect or guide the energy user decisions should be included. However, there are number of different approaches to model energy demand. According to [5] there is no single 'right' approach to modelling energy demand, the modelling strategy might differ according to a range of conditions and here are different approaches and studies in the literature aiming to model energy demand that can be categorized into three main groups: i) end-use modelling; ii) input-output modelling; iii) econometric modelling. Time series analysis has been proven to be the best because of its simplicity in approach.

End-use approach was developed to identify the role of each end-use towards the aggregate energy consumption. One of the earliest studies using the end-use modeling approach or engineering-economy approach (also known as the bottom up approach) was [8]. In reviewing a range of energy demand models for policy formulation point out that most end-use demand models do not rely on neo-classical economic theory. Moreover, they do not focus on history; instead, they identify recent structural changes and technological developments, which is arguably the main strength of this approach [7].

Models in energy forecasting

- *Energy estimation has been carried using so many methods, for instance Wassily [10] [7] uses input – output models to estimate. Also, The econometric modeling approach of energy demand, the Non-Stationary and the Co-integration Technique [11] [12], Multivariate Co-integration System (Johansen Approach) [13], and the Structural Time Series Model (STSM) [14] [15] [16].*

METHODOLOGY

Most of the studies on determinants of residential electricity demand functions have focused on developed countries. There are studies for Canada; the United States [17]; Mexico [18] and the United Kingdom [19]. For Asia–Pacific countries, such as Australia, India and Taiwan [20]; European countries, such as Greece, Norway, Cyprus and Switzerland [21]; in G7 co countries [21] and countries in the Middle East [22]. There is a paucity of research on energy demand in developing countries and only a few of the studies accounted for the time-series properties of the response of energy consumption to changes in income and relevant prices.
There is a glaring gap in Sub-Saharan Africa (except for [23] for South Africa and [24] for Namibia despite the importance of improved and more robust estimates of electricity demand parameters in better electricity policy decision making and implementation. The central role of the residential demand for electricity in the Nigeria economy, the controversies about appropriate pricing and the twin issue of IPPs coupled with the inadequate supply of

electricity in the country strongly suggest that more accurate estimates of this elasticity are of paramount policy importance.

A diversity of approaches to the estimation of electricity demand can be found in the literature ranging from aggregative analysis of the relationship between electricity demand, income and prices [25], to more detailed disaggregated analysis [26]; based on simultaneous model structure. In the most basic model, the demand for electricity, has been modeled as a function of a single variable, such as real income or temperature; real income and prices [27] real income, residential electricity price and price of natural gas [28]; real income, electricity prices, population growth, structural changes in the economy and efficiency improvement [29] population, income, price of electricity, price of oil, urbanization, weather; real income, price of electricity and diesel (used in for captive power generation to meet the shortages), and reliability of power supply from utilities real income, the real price of electricity, and the variable that captures the seasonal component of the demand for electricity.

These set of studies examined the residential demand for electricity in the context of household production theory. If unconstrained by data limitations, studies of the empirical model of the residential demand for electricity are based on household production theory which can be expressed as a function of own price, price of a substitute source of energy, real income, price of household appliances and other factors that may influence household preferences, such as temperature. In practice, most existing studies have not been able to get data on all these potential explanatory variables. We therefore include price of electricity population, price of substitute and real income as determinants of the residential demand for electricity in Nigeria.

[21] To analyzed the residential demand for electricity in Australia. They estimated two models of the residential demand for electricity. Both models include income and temperature variables, but differ in their representation of the price variable. In the first model, in addition to the income and temperature variables, the prices of electricity and natural gas (a substitute source of energy) are introduced as separate variables. In the second model the specification of the price takes the relative price format. In the long run, they found that income and own prices are the most important determinants of residential electricity demand, while temperature is significant some of the time and gas prices are insignificant. In addition, the short-run elasticity are much smaller than the long-run elasticity, and the coefficients on the error correction coefficients are small consistent with the fact that in the short-run energy appliances are fixed. Similarly, in a study of residential demand for electricity in a panel of G7 countries, [21]) use similar model specifications.

Population is another important factor to determine electricity demand in Nigeria. Higher population level is expected to increase electricity consumption. A positive correlation between population growth and electricity demand is therefore expected.

Economic theory suggests that electricity purchases will depend on the prices of substitutes: natural gas and petroleum products. However, the independent influences of diesel and gasoline prices may be rather small because a sizeable number of people in Nigeria do not have access to a power generating set to generate electricity when there is power outage. In our view, natural gas is not also appropriate in the case of Taiwan, since its consumption is concentrated on the urban rich and can be said to be comparatively small.

Results and Discussion

4.1 Residential Forecasts, *The residential demand forecast is performed using the data below:*

	ENERGY CONSUMPTION (MW)			
YEAR	***INDUSTRIAL***	***COMMERCIAL***	***RESIDENTIAL***	***TOTAL***
2000	*1011.60*	*2346.00*	*4608.40*	*8688.90*
2001	*1987.20*	*2439.00*	*7714.80*	*9034.40*
2002	*1830.00*	*3297.60*	*7668.50*	*12842.40*
2003	*1659.80*	*3583.00*	*7668.50*	*12866.60*
2004	*1605.00*	*3830.30*	*7725.30*	*13160.60*
2005	*1615.50*	*3851.00*	*7760.00*	*13226.60*
2006	*1575.00*	*3900.80*	*7650.00*	*13125.80*
2007	*1530.50*	*3915.00*	*7860.30*	*13305.80*
2008	*1502.50*	*3852.00*	*7910.08*	*13264.55*
2009	*1585.00*	*3865.50*	*8075.00*	*13525.50*
2010	*1589.40*	*3925.80*	*8205.20*	*13720.40*
2011	*1615.50*	*4004.70*	*8285.60*	*13905.80*
2012	*1648.00*	*4025.40*	*8350.00*	*14023.40*
2013	*1615.08*	*4424.78*	*8773.13*	*14812.99*
2014	*1617.73*	*4542.21*	*8933.23*	*15093.17*
2015	*1620.38*	*4659.64*	*9093.33*	*15373.35*
2016	*1620.03*	*4777.07*	*9253.43*	*15650.53*
2017	*1625.68*	*4894.50*	*9413.53*	*15933.71*

Source: Central Bank of Nigeria STATISTICAL BULLETIN and National Bureau of Statistics (NBS).

The table shown above are the values of electricity consumption in Nigeria for residential, commercial and industrial sectors respectively. This forms the basis for our analysis and forecast to get the anticipated energy demand for 2030 using time series.

4.2 Residential Forecasts, *The residential demand forecast is performed using the data below:*

Year	***T***	***Residential demand (MW) y***	***Ty***	t^2
2000	*-6*	*4608.40*	*-27650.40*	*36*
2001	*-5*	*7714.80*	*-38574.00*	*25*
2002	*-4*	*7668.50*	*-30674.00*	*16*
2003	*-3*	*7668.50*	*-23005.50*	*9*
2004	*-2*	*7725.30*	*-15450.60*	*4*
2005	*-1*	*7760.00*	*-7760.00*	*1*
2006	*0*	*7650.00*	*0.00*	*0*
2007	*1*	*7860.30*	*7860.30*	*1*
2008	*2*	*7910.008*	*15820.16*	*4*
2009	*3*	*8075.00*	*24225.00*	*9*

2010	*4*	*8205.20*	*32820.80*	*16*
2011	*5*	*8285.60*	*41428.00*	*25*
2012	*6*	*8350.00*	*50100.00*	*36*
Total	*0*	*99481.68*	*29139.76*	*182*

From table 4.2 above, is an extract of the values for residential energy consumption from year 2000 – 2012 which was calculated to get the the trend values and then we will proceed to generate the forecasted result using the formula below.

From $Y = a + bt$ ....*(1)*

Where;

$a = \frac{\sum y}{n} - \frac{b \sum t}{n}$ ....*(2)*

= trend line value when t = 0,

$b = \frac{b \sum ty - \sum t \sum y}{n \sum t2 - (\sum t)2}$ ....*(3)*

= gradient of the trend line

Table 4.3: Trend Values

Year	***Residential Demand (MW) y***	***Trend value Y (MW)***
2000	*4608.40*	*6691.83*
2001	*7714.80*	*6851.93*
2002	*7668.50*	*7172.13*
2003	*7668.50*	*7172.13*
2004	*7725.30*	*7332.23*
2005	*7760.00*	*7492.33*
2006	*7650.00*	*7652.43*
2007	*7860.30*	*7812.53*
2008	*7910.05*	*7972.63*
2009	*8075.00*	*8132.73*
2010	*8205.20*	*8292.83*
2011	*8285.60*	*8452.93*
2012	*8350.00*	*8613.03*
Total	*99481.68*	*99481.59*

Table 4.2 generated the values for table 4.3 as shown above

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I. Calculating the Accuracy of Residential Forecast

The Mean Absolute Deviation $MAD = Actual - ForecastN = 6.92*10-3$

II. Predicted Residential Demand

The forecast value is gotten by either adding the trend line value (160.10MW) to the preceding load demand to get the current years forecast demand or by using the trend equation [7] to give the table below;

Table 4.4: Table of Predicted Residential Demand Values

Year	*Residential Forecast Demand Y(MW)*
2018	*9573.63*
2019	*9733.73*
2020	*9893.83*
2021	*10053.93*
2022	*10214.03*
2023	*10374.13*
2024	*10534.23*
2025	*10694.33*
2026	*10854.43*
2027	*11014.53*
2028	*11174.63*
2029	*11334.73*
2030	*11494.83*

Table 4.4 above shows the actual forecasted values of residential energy demand from 2018 to 2030. But this is not the total energy demand since during energy generation and transmission, the same power generated and supplied are used intermittently to feed the commercial and industrial areas as well. So because of this the same procedure used for calculating the forecasted energy demand for residential areas is also deployed for both commercial and industrial. The summation of the individual actual forecasted values for residential, commercial and industrial gives rise to the total predicted energy demand values from 2018-2030 as shown in the table below.

4.4 Total Predicted Demand

The total Predicted demand is gotten by summing the individual demand forecast of residential, commercial and industrial. The table is shown below;

Table 4.10: Total Predicted Load Demand

Year	*Predicted Load Demand(MW)*
2018	*16213.89*
2019	*16494.07*
2020	*16774.25*
2021	*17054.43*
2022	*17334.61*
2023	*17614.79*
2024	*17894.97*
2025	*18175.15*
2026	*18455.33*
2027	*18735.51*
2028	*19015.69*
2029	*19295.87*
2030	*19576.05*

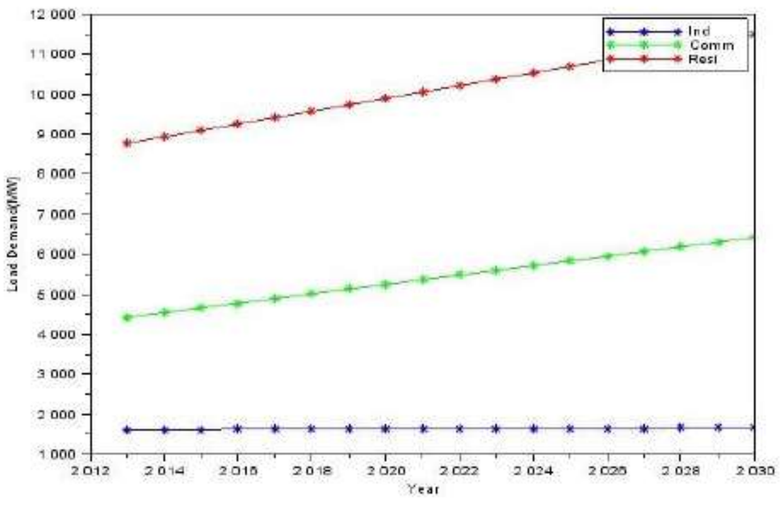


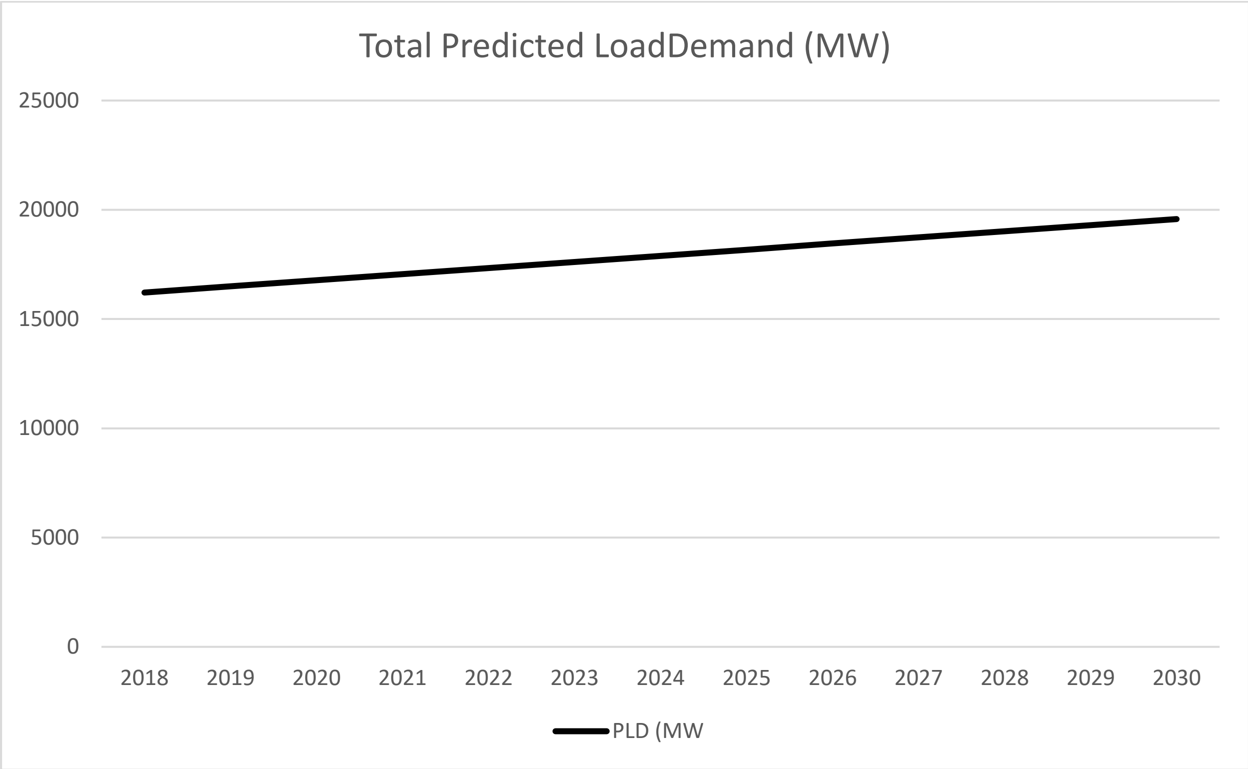
Figure 3.0: Graph of total forecasted energy demand for both residential, commercial and industrial areas in Nigeria from 2012-2030. A comparism between figure 1 and 3 will show clearly that figure 1 graph of energy generated from 1970-2000 could not give us straight line but that of figure 3 of the estimated electric energy demand forecat from 2018-2030 does. By this result , it simply comply to the law of demand and supply in economics,the straight lines obtained for both resiodentai, commercial and industrial validates our analysis that if a total energy of approximately 20,000mw is generated within the time under consideration, it will go a long way to improve the standard of living in Nigeria and also enhance industrialization and economic groth.

4.5 System Implementation

Year	*Residential Forecasted Demand Y (MW)*
2013	*8773.13*
2014	*8933.23*
2015	*9093.33*
2016	*9253.43*
2017	*9413.53*
2018	*9573.63*
2019	*9733.73*
2020	*9893.83*
2021	*10053.93*
2022	*10214.03*
2023	*10374.13*
2024	*10534.23*
2025	*10694.33*
2026	*10854.43*
2027	*11014.53*
2028	*11174.63*
2029	*11334.73*
2030	*11494.83*

Figure 4.5 the total forecasted values for residential energy demand from 2018 -2030. Since our emphasis in this paper is residential energy demand forecast using time series as a tool for analysis ,hence our result presented above. When plotted in a graph, it gives rise to a

straight line indicating that the demand at that time period , if such an amount or quantity of energy is being generated, it will efficiently affordably serve the residential populace of Nigeria.



5.1 Summary

Electricity supply in Nigeria is grossly inadequate, total installed capacity is far less than the demand and out of this installed capacity the available capacity is barely above half of the installed capacity. The per capita energy consumption is too low for meaningful economic and social development. The result of this project shows that, a total 19,576.05MW energy is needed in Nigeria to efficiently and affordably service the residential areas. A holistic plan of energy generation and supply should be in place, while adequate measures are put in places to achieve the set targeted energy demand of approximately 20,000MW by the year 2030.

5.2 Conclusion

Having investigated the Nigeria power sector, it is observed that there is inadequate power supply due to insufficient power generation. The results of this research work has shown that Nigeria need to build more power generation plants and invest in her power *sector to achieved the target forecasted values of 19,576.05MW. In order to efficiently and affordably supply her residence.*

5.3 Recommendation

The outcome of this project should guide the energy policy makers in Nigeria aimed at building more power plants and to increase more budgetary allocation to the power sector in order to achieved the estimated approximate 20, 000MW power by the year 2030.

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